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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 : B29C 47/62, 47/64	A1	(11) International Publication Number: WO 88/ 01227 (43) International Publication Date: 25 February 1988 (25.02.88)

(21) International Application Number: PCT/US87/02062

(22) International Filing Date: 19 August 1987 (19.08.87)

(31) Priority Application Number: 897,987

(32) Priority Date: 19 August 1986 (19.08.86)

(33) Priority Country: US

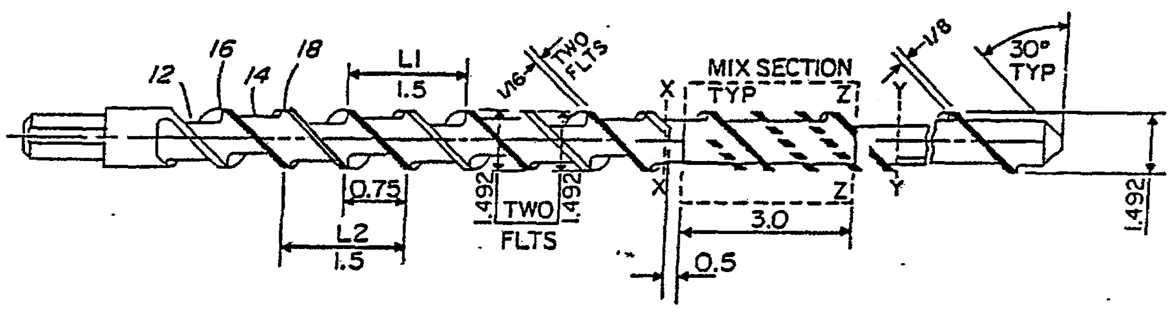
(71)(72) Applicants and Inventors: ALZNER, Bernard, G. [US/US]; 41 East North Avenue, Lake Forest, IL 60045 (US). CSONGOR, Desider, G. [US/US]; 19 Bennett Street, Manchester, MA 01944 (US).

(74) Agents: SMITH, James, M. et al.; Hamilton, Brook, Smith & Reynolds, Two Militia Drive, Lexington, MA 02173 (US).

(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), HU, IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), SU.

Published
With international search report.

(54) Title: PLASTICISING EXTRUDER SCREW



(57) Abstract

A plasticating extruder screw effectively broadens the useful operating range of the single screw extruder by incorporating two or more screw configurations into a single screw. This is accomplished with two or more parallel channels (12, 14) in which each channel is designed to a different set of materials and performance requirements reflecting the range of the materials to be processed. The extrusion screw in fact represents two or more screws in a single screw in which each performs its function independently of the other. Thus, each channel in this screw differs from the others in critical design parameters such as compression ratio, length and depth of its feed, transition and metering zones. This multiconfigurational design feature may occupy part or the entire length of the extruder as dictated by the specific characteristics of the materials to be processed. A mixing and stabilization zone placed at or near the entrance of the metering zone of the screw provides for melt flow interaction and equilibration between channels. The screw terminates in a metering zone comprised of one or more channels designed in accordance with known principles.

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Plasticising extruder screw.

Background of the Invention

Extrusion screws featuring two or more parallel channels are among the first types of screws used in the trade. These screws, in which all channels within a given screw are of identical configuration, usually of relatively low compression ratio as measured by the ratio of feed to meter channel depth. These types of screws were replaced by the single channel screw which was found to be more effective than the multichannel screw described above. Increasing emphasis was placed on optimization of the single channel screw with the aid of computer programs as these became available. While these developments produced considerable performance improvements they, nevertheless, failed to cope with the variability in materials and process encountered in the trade.

The last decade witnessed the appearance of several unique types of extrusion screws intended to overcome the variability problems described. The most noteworthy of these developments is the barrier screw. While many variations of the basic barrier concept were produced, they all feature a nonparallel minor flight in the transition, i.e. melting, zone whose purpose is to separate the solid from the melt where these two phases coexist. It accomplishes this by allowing the melt to pass over the minor flight which is of a lesser height than the major flight while containing the solid pellets in the original channel. The minor flight is faced out at the calculated point of complete conversion

of solid to melt. This condition is only realized when design parameters are satisfied which is rarely the case in practice.

Summary of the Invention

In accordance with the present invention, an extruder plasticizing screw comprises two or more parallel channels defined by parallel flights. Each channel is of unique configuration relative to width, depth and/or length of its functional feed transition and/or metering zones. Each channel receives the supply of material, but each is designed to a different set of material characteristics in order to extend the range of materials which can be handled by the screw. The output of the two channels is mixed in a mixer which may be incorporated onto the screw. The flights defining the channels provide minimal clearance to minimize interference between the channels prior to mixing.

Preferably, the melt emerging from the channels is pooled in a single channel. The single channel has a cross-sectional area adjacent to the exit end of the multichanneled section at least 20 percent greater than the cross-sectional area of the discharge end of the multichanneled section.

Brief Description of the Drawings

Figure 1 illustrates the performance characteristics of a screw embodying the present invention and of a commercially available barrier mixer type of screw.

Figure 2A is a side view of a screw embodying the present invention, Figure 2B is the root diameter profile of the screw, and Figure 2C sets forth additional design parameters of the screw.

Preferred Embodiment

The screw is the heart of any extruder. It performs all of the essential functions of the extruder which include solids conveying and compacting, melting, mixing and homogenization of the melt, and pumping which it must do at a consistent rate. Failure in any one of these functions will adversely affect the others. Optimum performance of these functions is achieved through the development of a screw configuration dictated by specific materials and performance characteristics. The polymeric material processed by such extruders is usually supplied in pellet, powder or granular form. It is well known in the art that these materials differ widely in their processing characteristics. In fact, lot to lot variations within a specific type or brand of polymer from a single source is not uncommon. The use of scrap necessitated by economic considerations further aggregates variability in the feed stock as dissimilar particles exhibit different processing characteristics. This can cause destabilization in the feed and melting zones which usually remain uncorrected in the metering zone. It is a common practice among convertors to resort to the use of several screws to effectively cope with such material variability.

It is the objective of this invention to provide a multiconfigurational screw in a single

screw which has a broader useful operating range than is obtainable with a single configuration. This is accomplished by incorporating two or more parallel channels in critical portions of the screw in which each channel is optimized to a different set of materials and performance characteristics reflecting the variability encountered in the material to be processed. The flights separating the channels are designed to a minimum clearance so that each channel functions with the minimum interference from adjacent channels. Each channel thus formed differs from the other in important design parameters such as compression ratio, length and depth of its zones particularly its feed and transition zones. Each channel is designed for optimum performance to different materials and performance requirements dictated by variations encountered in the material and process. Problems developed in one channel will be compensated for in the other with the configuration better matched to the material processed. A mixing and flow stabilization zone placed in the metering zone near the end of the multi-configurational section of the screw insures equilibration and stabilization of the melt quality and flow.

The multiconfigurational screw of the invention was found to exhibit a broader operating range than is obtained with single channel screws and other types known in the trade. Performance characteristics of such a screw are depicted for a number of difficult to process polymers in Figure 1. A similar performance study performed on a screw enjoying wide customer acceptance in the trade

is depicted in Figure 1. While the commercial screw of Figure 1 exhibits a decline in its pumping efficiency with increasing output, i.e. RPM as measured by its displacement in pounds per revolution, the screw of this invention exhibited constant and, in some cases, improved pumping efficiency with increasing RPM. This result is particularly surprising in the case of the high density polyethylene, both of which are known for their poor processing characteristics. The other surprising fact revealed in this study is the wide range of dissimilar materials so effectively processed in the screw of this invention.

Another less obvious benefit attributable to high pumping efficiency is the reduction in shear energy per pound of material processed which should be kept to a minimum with most polymers.

Still another advantage observed with the type of screw described herein is in the dimensional consistency of the extrudate as measured by the mean and standard deviation data shown below in comparison to a standard. Accordingly, the screw of subject invention exhibits less fluctuations and greater tolerance for materials related variables than the standard used in these tests. The standard is a barrier type screw which enjoys considerable popularity in the trade.

Variations in film thickness
at 60 screw RPM observed with the commercial
and multiconfigurational screws

MATERIAL	MI	COM. (STD) GA(mils)	SCREW STD.D	MULTICONFIGURATIONAL GA(mils)	STD.D
HDPE 'A'	0.4	4.1	0.7	4.2	0.3
HDPE 'B'	0.6	4.8	0.5	4.7	0.2
LLDPE	1.5	4.5	0.9	4.6	0.6
Mod'd'A'	0.7	4.3	0.4	4.4	0.4

The essential design features of the extrusion screw described above are detailed in Figures 2A-2C. Accordingly, said screw contains two or more parallel channels 12 and 14 separated by parallel flights 16 and 18 in the feed zone and at least in 50% of the transition zone. It is essential that each channel in this section of the screw is designed to a different set of design parameters defining the range of variability encountered with the materials to be processed. In this example the configurational differences were developed for optimum solid conveying and melting of polymeric material differing in bulk density as is the case with the inclusion of reclaimed scrap in virgin resin at varying concentrations. The resulting channels exhibit significant configurational differences in the feed, transition and metering zones as illustrated in Figure 2A-2C.

In particular, it can be noted from the root diameter profile of Figure 2B and the number of

turns indicated in Figure 2C that each zone is of a different length for each channel. In particular, the first channel has a feed zone of 4.5 inches and three turns, a transition zone of 13.5 inches and nine turns and a meter zone of 3 inches and two turns. The second channel on the other hand has a feed zone of twice the length, 9 inches and six turns, a transition zone of 10.5 inches and seven turns and a meter zone of only 1.5 inches and one turn. The lengths L1 and L2 between common points on each flight remain constant for both flights at 1.5 inches. The depths of the channels vary differently as illustrated by the broken and solid lines of Figure 2B and the dimensions set forth in Figure 2C. The first channel has a compression ratio at XX of 2.8, and the second channel has a compression ratio of 2.0.

An important element in this screw consists of a mixing and stabilization zone placed at or near the end of the multichanneled section. Any mixing configuration known in the art may perform adequately. In its simplest form, this zone may be comprised of a single channel having a melt volume cross-sectional area, YY, at least 20 percent greater than the combined cross-sectional areas of the preceding multi-channelled section, XX. Melt mixing and stabilization is further enhanced by a complete interruption of the flights for a short interval, i.e. .25 to approximately 1 inch, at the entrance of the decompression point, YY, preferably between the mixing and the decompression sections, i.e. at ZZ on the drawing. The sequence of mixers, interrupted flight portion and decompression channel

comprising an effective melt mixing and flow stabilization zone. The screw is terminated at the discharge end by a single or multichanneled metering section designed in accordance to know principles of extrusion.

CLAIMS

1. An extruder plasticating screw comprised of two or more parallel channels defined by parallel flights in which each channel is of unique configuration.

2. An extrusion screw as claimed in Claim 1 in which the feed zone and at least 50 percent of the transition or melting zone is comprised of two or more parallel channels.

3. An extrusion screw as claimed in Claim 1 in which each channel is designed to a different set of materials characteristics.

4. An extrusion screw as claimed in Claim 1 in which each channel is designed to a different set of process requirements.

5. An extrusion screw as claimed in Claim 1 in which each channel differs from the other in at least one of several dimensional characteristics including width, depth or length of its functional zones which include the feed, transition or melting, and metering zones.

6. An extrusion screw as claimed in Claim 1 in which the melt emerging from the various channels is 'pooled' in a single channel.

7. An extrusion screw as claimed in Claim 1 in which the melt emerging from the various channels is combined and mixed in a common mixing section.

8. A screw as claimed in Claim 6 in which the single channel has a cross sectional area adjacent to the exit end of the multichannelled section at least 20 percent greater than the cross sectional area of the discharge end of the multichannelled zone or section.

9. A screw as claimed in Claim 8 which has a melt mixing and stabilizing zone comprised of a mixing section as described in which the melt emerging from the various channels is combined and mixed.

10. An extrusion screw as claimed in Claim 9 containing a melt mixing and stabilizing zone comprised of a mixing section followed by a decompression channel in which the channel flight(s) are completely interrupted for a short interval between the mixing and decompression channel, said interval being about 0.25- to 1 inch in length.

11. An extrusion screw as claimed in Claim 1 which terminates at the discharge end in a single or multichannel metering section.

12. An extrusion screw as claimed in Claim 1 wherein each of the two or more parallel channels includes a feed, transition and meter zone, the lengths of the zones differing between channels.

13. An extrusion screw as claimed in Claim 1 wherein the flights provide minimal clearance to minimize interference between channels.

14. An extruder incorporating the screw of Claim 1 further comprising a single feed to both channels and means for mixing the outputs of the two channels.

FIG. 1

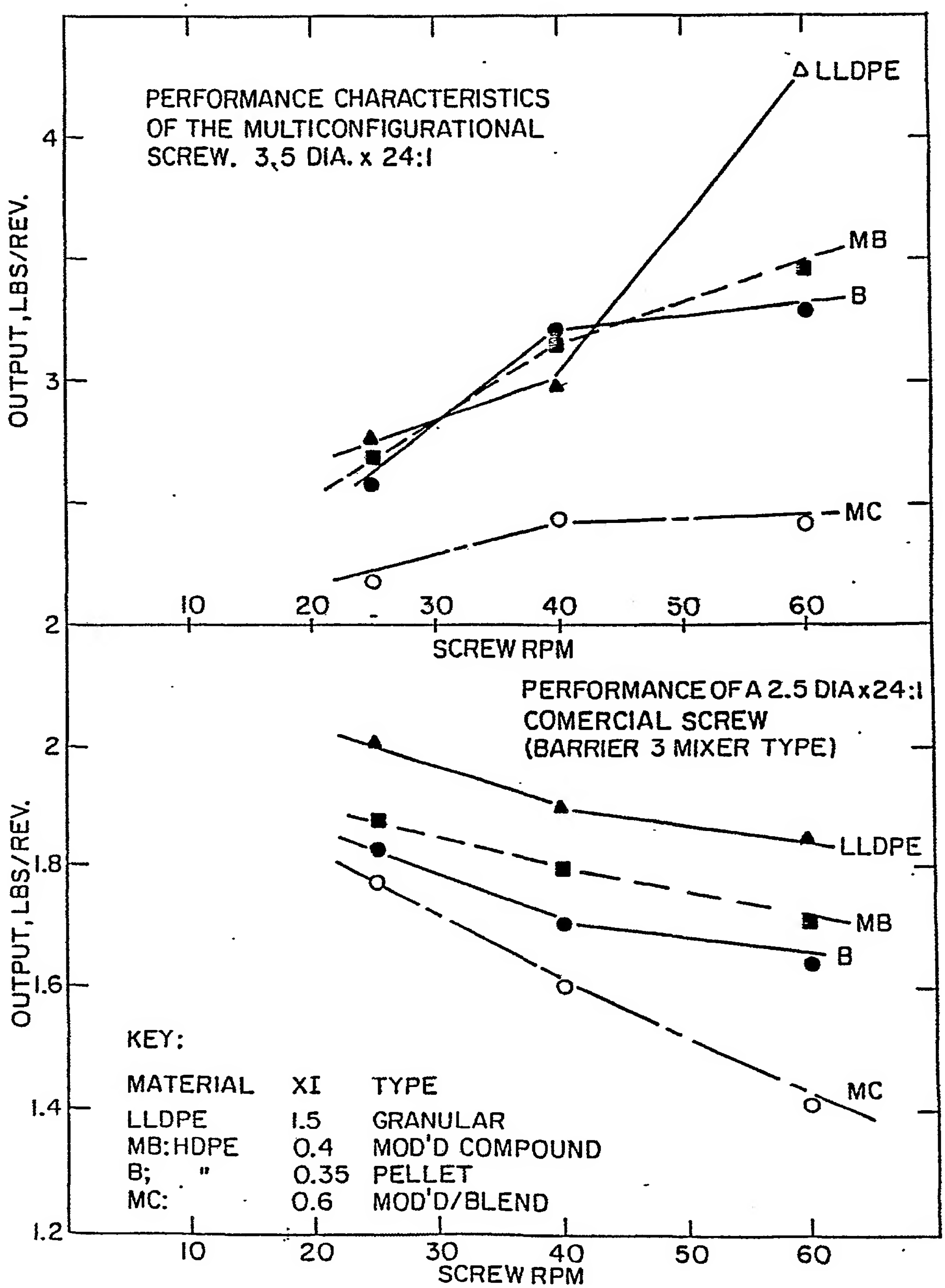
PERFORMANCE CHARACTERISTICS
OF THE MULTICONFIGURATIONAL
SCREW. 3.5 DIA. x 24:1
OUTPUT, LBS/REV.
SCREW RPM
LLDPE
MB
B
MC
PERFORMANCE OF A 2.5 DIA x 24:1
COMERCIAL SCREW
(BARRIER 3 MIXER TYPE)
KEY:
MATERIAL XI TYPE
LLDPE 1.5 GRANULAR
MB: HDPE 0.4 MOD'D COMPOUND
B; " 0.35 PELLET
MC: 0.6 MOD'D/BLEND

FIG. 2A

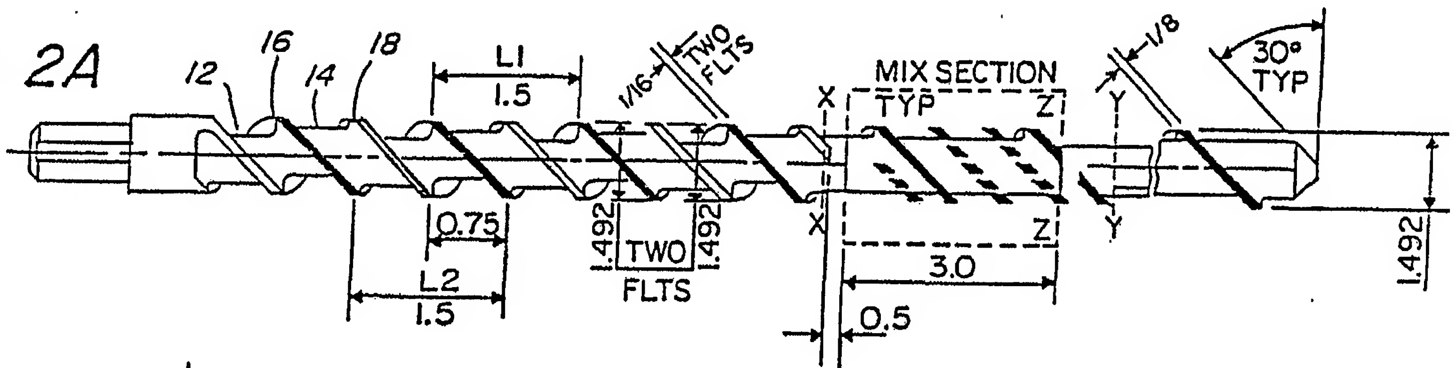

FIG. 2B

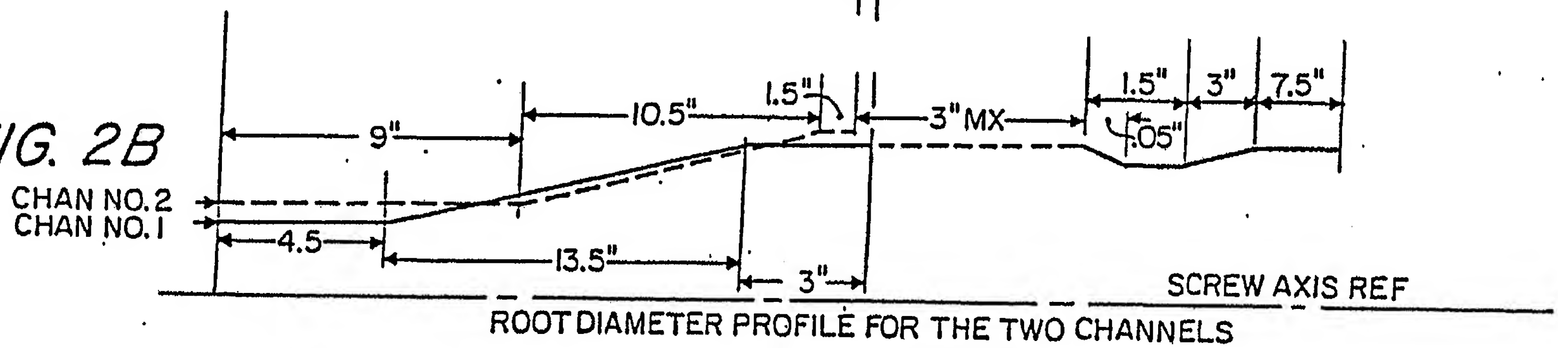

FIG. 2C

DESIGN SPECIFICATION
1.5 x 24:1 SCREW
COMPRESS RATIO AT XX: CHANNEL I: 2.8; CHANNEL 2: 2.0

ZONE	FEED	TRANSITION	IST METER	MIXING	FINAL METER FEED	FINAL METER TRANS	FINAL METER PUMP
CHAN: I L1	1.5	1.5	1.5	–	1.5	1.5	1.5
–NO. TURNS	3	9	2	2	1	2	5
–DEPTH	0.45	–	0.160	–	0.220	–	0.150
CHAN. II: L2	1.5	1.5	1.5	–	–		
–NO TURNS	6	7	1	–	–	–	–
–DEPTH	0.30	–	0.145	–	–	–	–

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 87/02062

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: B 29 C 47/62; B 29 C 47/64

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^4	B 29 C

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X Y	DE, A, 1909009 (F. KRUPP GmbH) 10 September 1970 see claims 1-4; figures 1-3	1-6,11-14 7-10
A Y	Patent Abstracts of Japan, volume 7, no. 12 (M-186)(1157), 19 January 1983, & JP, A, 57169337 (NIPPON SEIKOSHO K.K.) 19 October 1982	1-6,11-14 7-10
A	Patent Abstracts of Japan, volume 7, no. 215 (M-244)(1360), 22 September 1983, & JP, A, 58108118 (NIPPON SEIKOSHO K.K.) 28 June 1983	1-14
A	DE, A, 3501851 (BARMAG BARMER MASCHINENFABRIK AG) 14 August 1985 see abstract; claims; figure 1	1-5,12,13
A	US, A, 3912241 (U. OESTREICH) 14 October 1975	

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* Special categories of cited documents: [10]
"A" document defining the general state of the art which is not considered to be of particular relevance
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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
20th November 1987	10 DEC 1987
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	M. VAN MOL

Form PCT/ISA/210 (second sheet) (January 1985)

International Application No. PCT/US 87/02062

III. DOCUMENTS C NSIDERED TO BE RELEVANT (CONTINUED FR M THE SECOND SHEET)

Category*	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
	see claims 1-3; figure 1	1,2,6,8, 11,13,14
	--	
A	GB, A, 1590381 (J.K. NORMANTON et al.) 3 June 1981 see page 2, lines 33-43; figure 1	1-5,12,14
	--	
A	US, A, 4054403 (R.L. HORNBECK et al.) 18 October 1977 see column 1, lines 24-33; figure 1	1-5,12,13
	--	
A	GB, A, 2028218 (MANNESMANN DEMAG AG) 5 March 1980 see page 1, lines 110-113; figure 1	1-5,12,13
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A	US, A, 3713627 (M. SKOBEL) 30 January 1973 see claims; figures 1,6	1-5,12,13
	--	
A	DE, A, 3311176 (AEG-TELEFUNKEN KABELWERKE AG) 4 October 1984 see claims; figure 1	1-5,12,13
	--	
A	EP, A, 0034505 (W.H. WILLERT INC.) 26 August 1981 see abstract; figures 1-5	1-5

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/US 87/02062 (SA 18595)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 25/11/87

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DE-A- 1909009	10/09/70	FR-A-	2035544	18/12/70
		GB-A-	1299955	13/12/72
		SE-B-	354989	02/04/73
DE-A- 3501851	14/08/85	None		
US-A- 3912241	14/10/75	FR-A,B	2243067	04/04/75
		DE-A-	2346032	20/03/75
GB-A- 1590381	03/06/81	None		
US-A- 4054403	18/10/77	FR-A,B	2361998	17/03/78
		DE-A,B,C	2734857	23/02/78
		AU-A-	2681977	11/01/79
		JP-A-	53023353	03/03/78
		GB-A-	1573362	20/08/80
		AU-B-	509499	15/05/80
		CA-A-	1095210	10/02/81
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		FR-A,B	2152972	27/04/73
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		BE-A-	788823	14/03/73
		GB-A-	1365612	04/09/74
		CA-A-	958003	19/11/74
		JP-A-	48062040	30/08/73
DE-A- 3311176	04/10/84	None		
EP-A- 0034505	26/08/81	JP-A-	56135045	22/10/81
		US-A-	4330214	18/05/82

For more details about this annex :
see Official Journal of the European Patent Office, No. 12/82